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Howell

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[54] **METHOD FOR IMPROVING PRODUCTIVITY OF A WELL**

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[52] **U.S. Cl.** **166/265;** 166/306; 166/313

[58] **Field of Search** 166/265, 267, 305.1, 166/306, 313, 50

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,167,125	1/1965	Bryan	166/306
3,195,633	7/1965	Jacob	166/306
3,363,692	1/1968	Bishop	166/306
4,296,810	10/1981	Price	166/265
4,429,740	2/1984	Malinchak	166/305.1
4,766,957	8/1988	McIntyre	166/265
5,335,732	8/1994	McIntyre	166/313
5,366,011	11/1994	Jennings, Jr.	166/265

OTHER PUBLICATIONS

"What's new in artificial lift", Lea and Winkler, World Oil, Mar., 1994, vol. 215 No. 3, p. 51.

"Downhole Injection Pump lowers cost of natural gas well-water disposal", Hart's Oil and Gas World, Apr., 1994 vol. 86 No. 4 p. 38.

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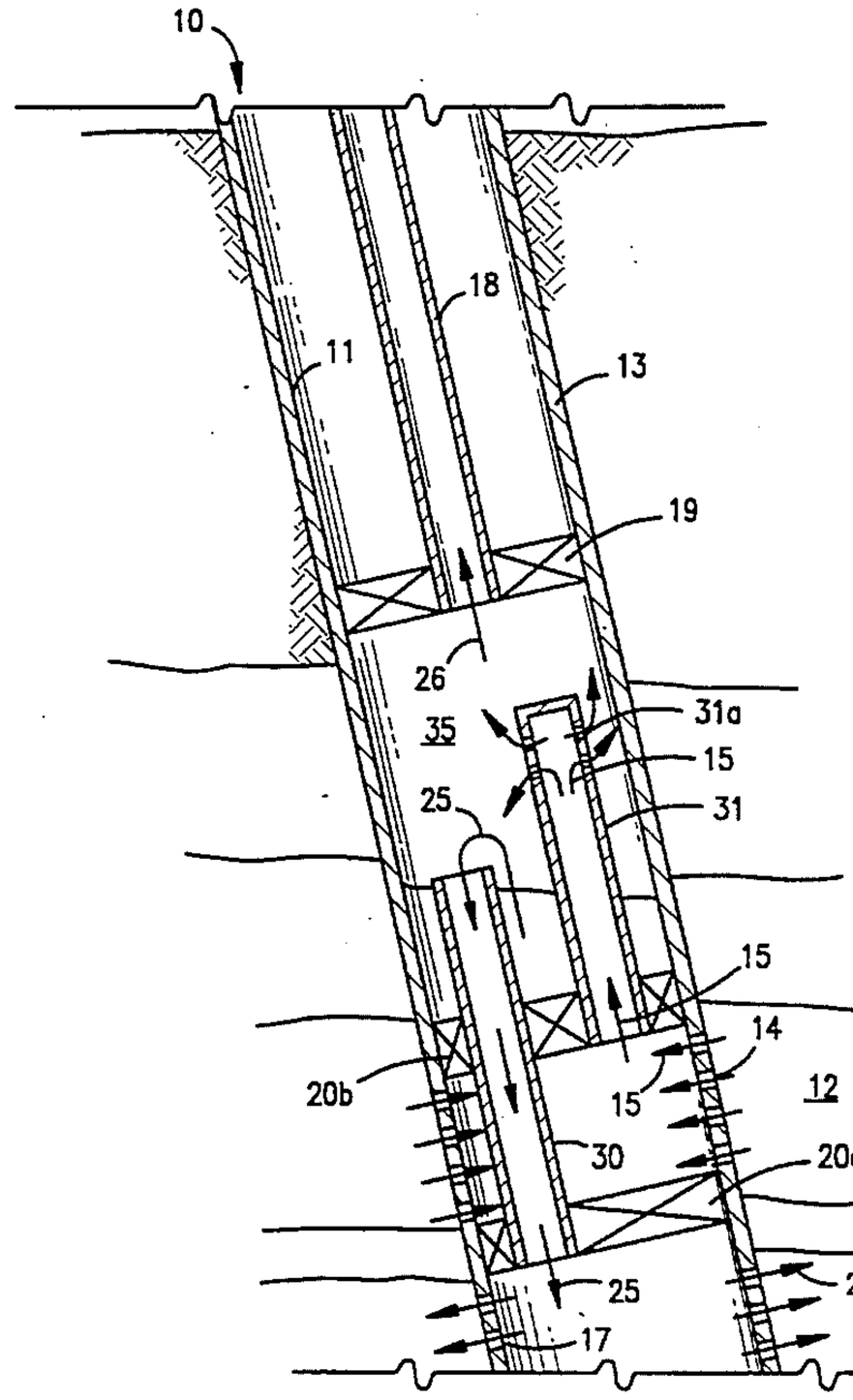
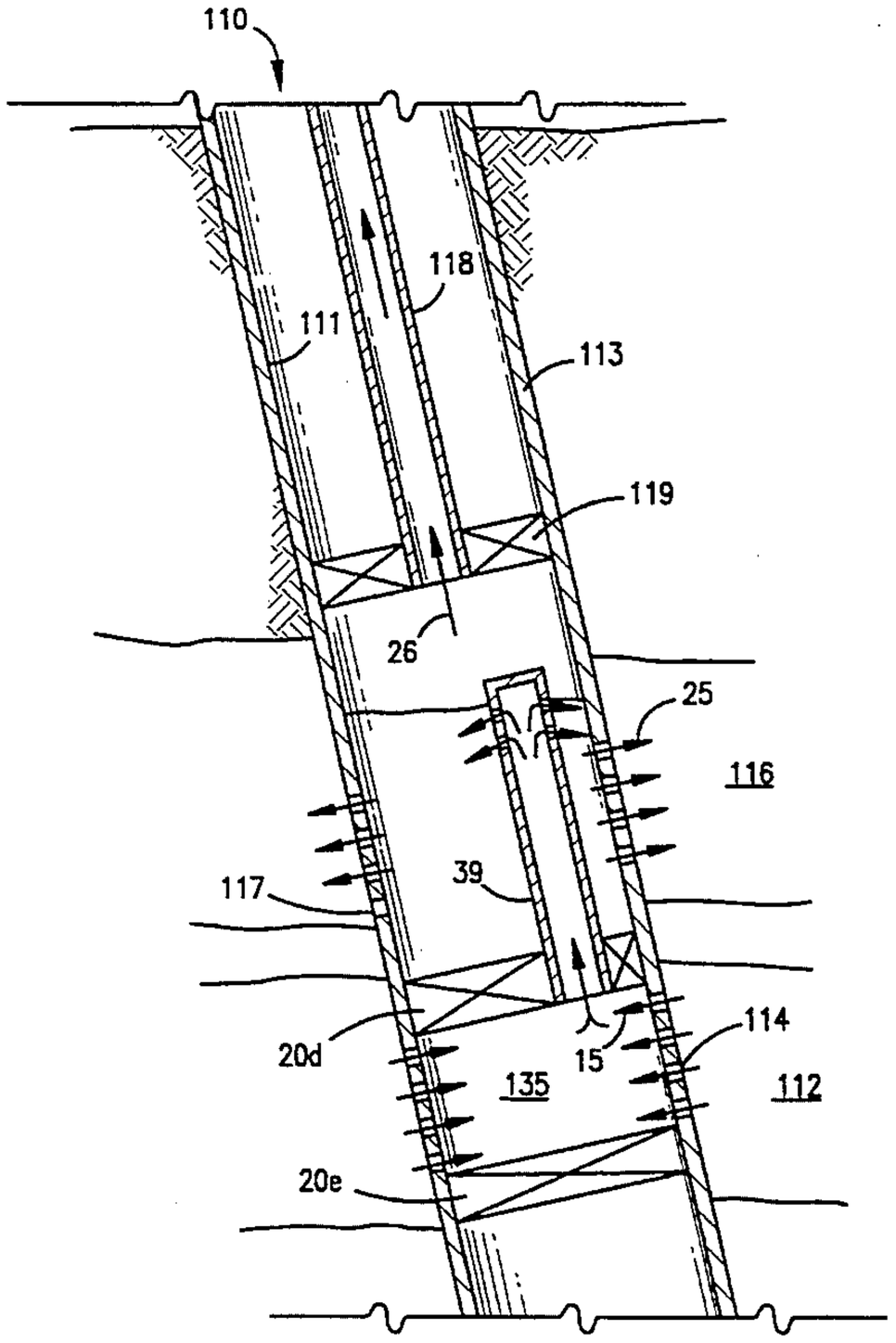
[57] **ABSTRACT**

A method for improving the productivity of a well by separating and disposing of at least a portion of the water which is produced from a subterranean producing formation. The water is allowed to separate from the produced fluids under the influence of gravity while in the wellbore. The separated water is then disposed without removing it from the wellbore by flowing it into a subterranean disposal formation which has a pressure less than that of said producing formation. Preferably, the well is completed with an inclined wellbore which significantly aids in the gravity separation of the water from the produced fluids (e.g. hydrocarbons).

4 Claims, 5 Drawing Sheets





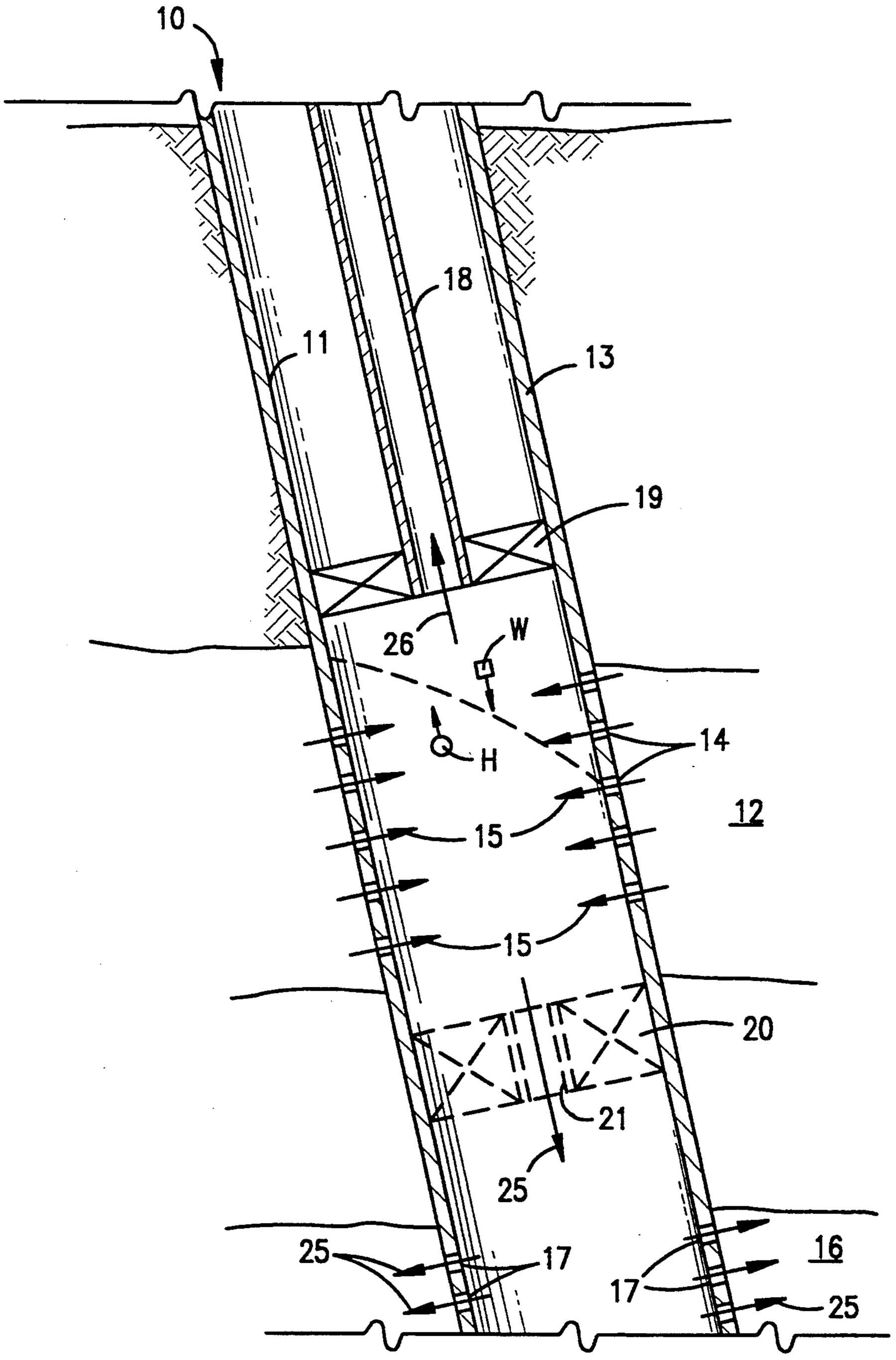


FIG. 1

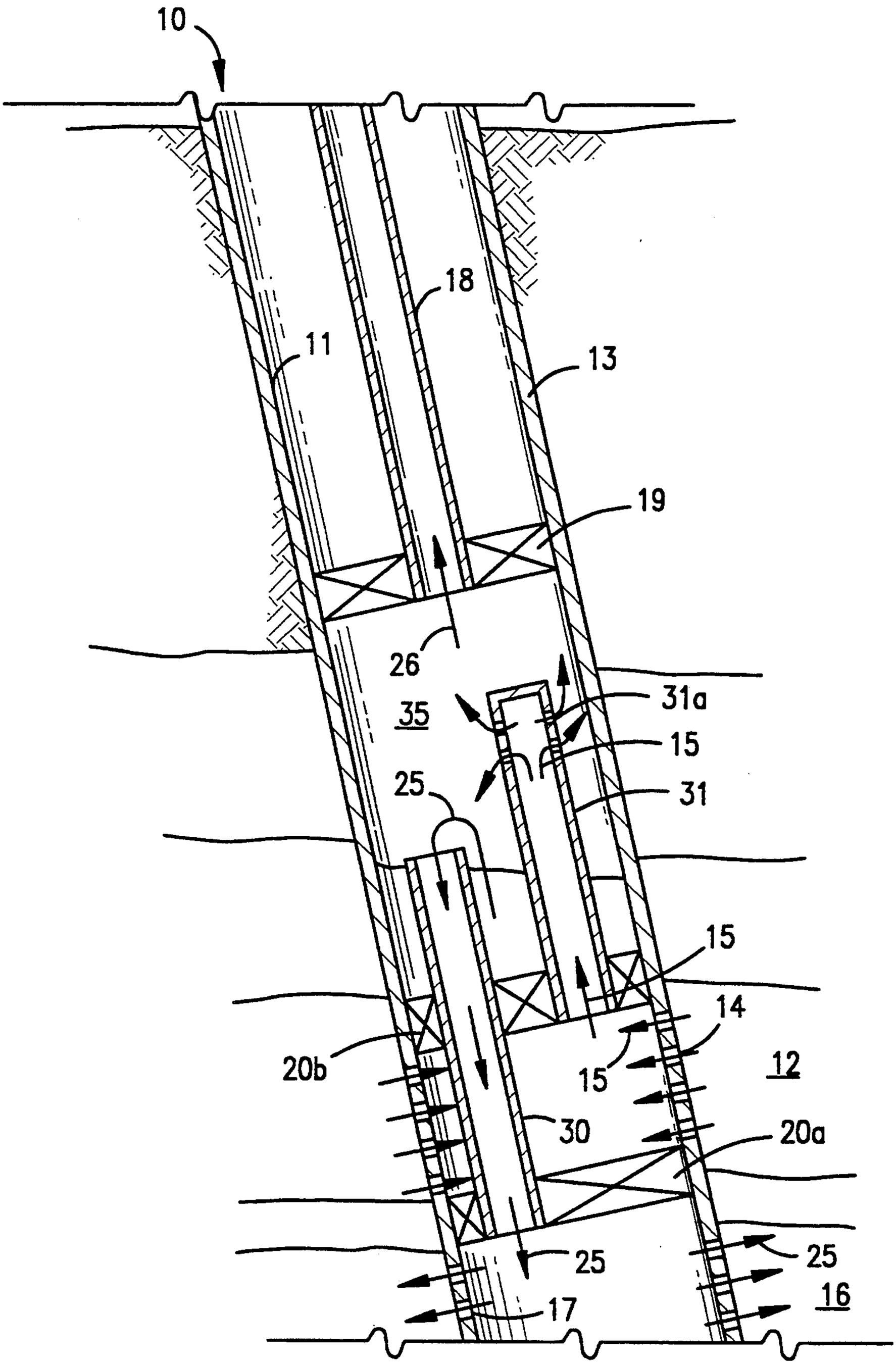


FIG. 2

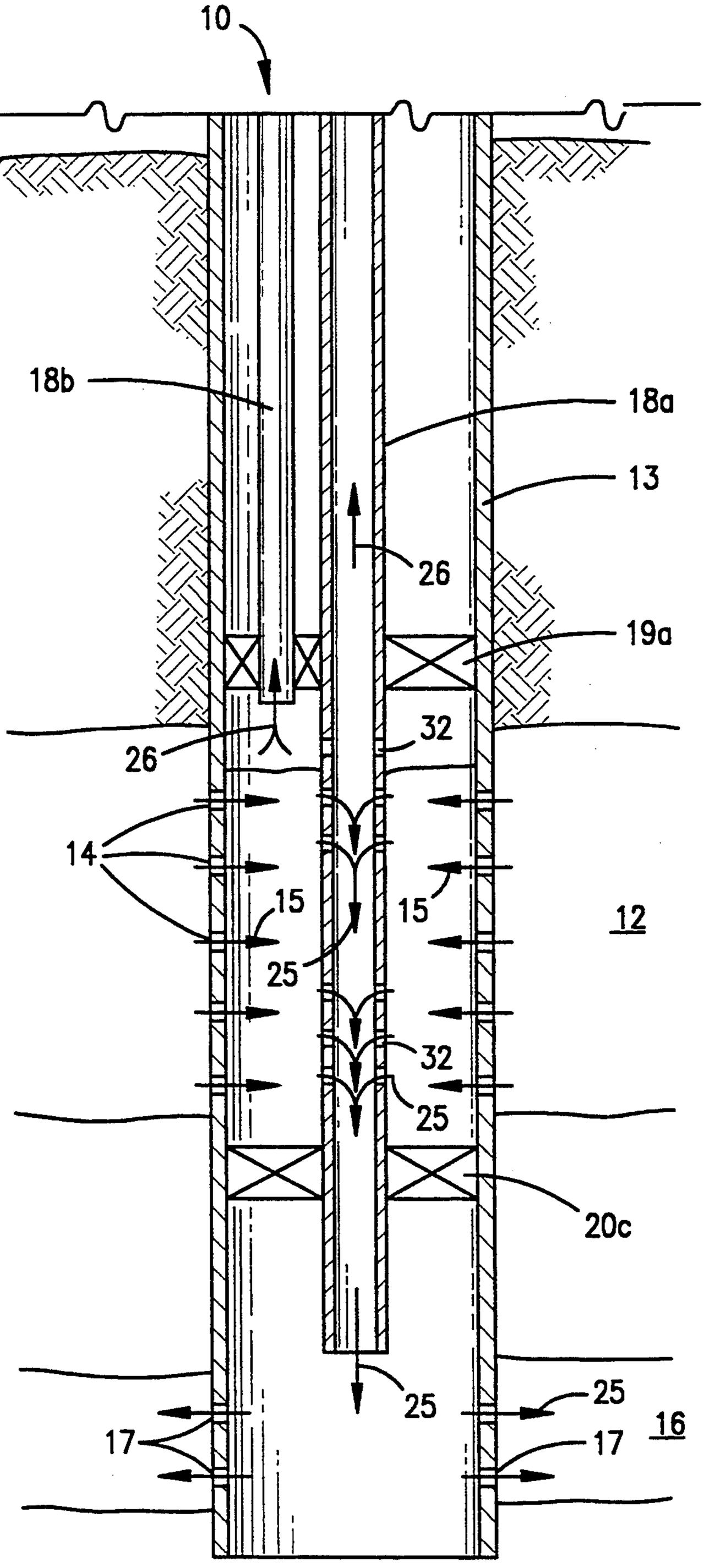


FIG. 3

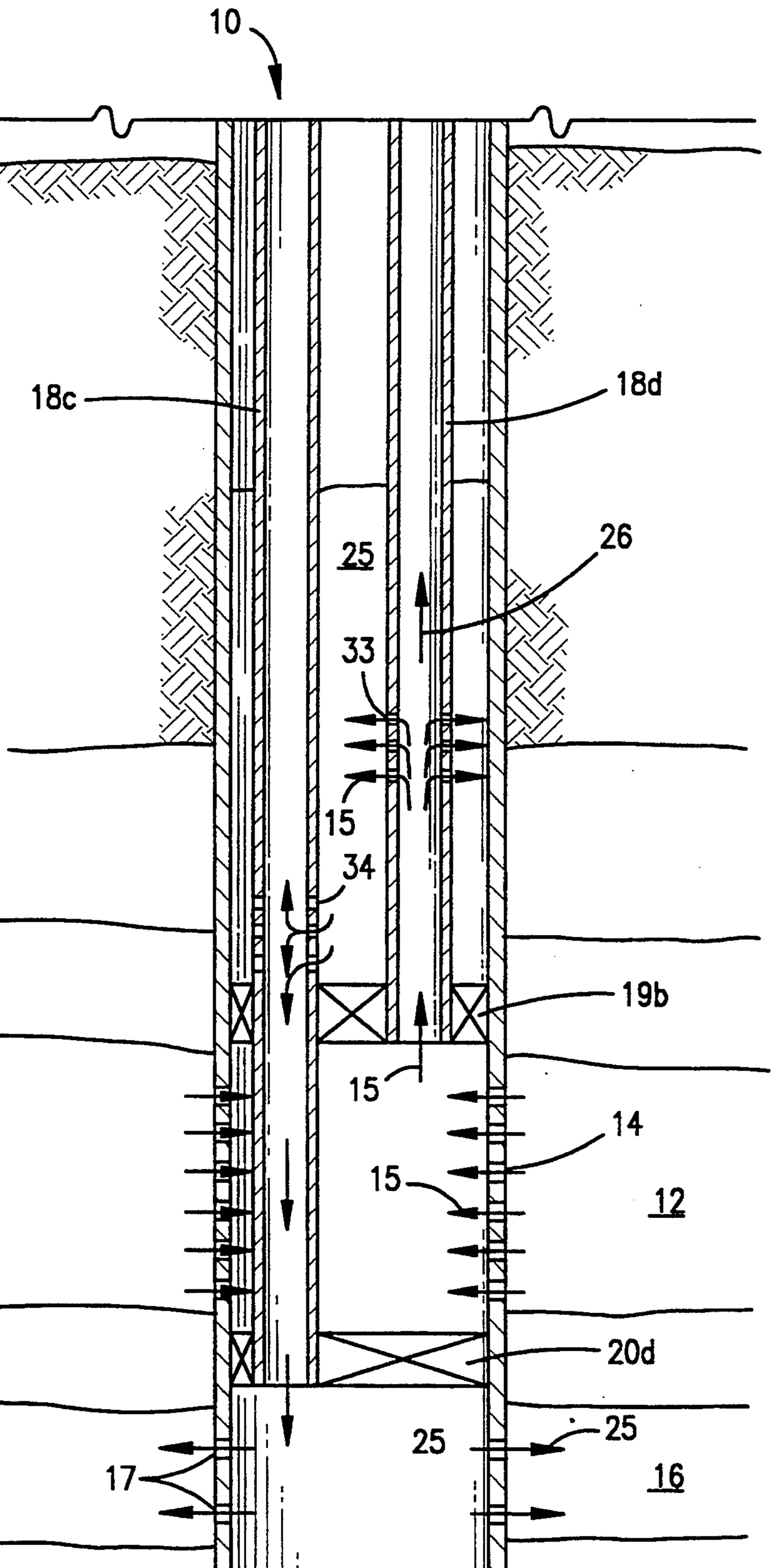


FIG. 4

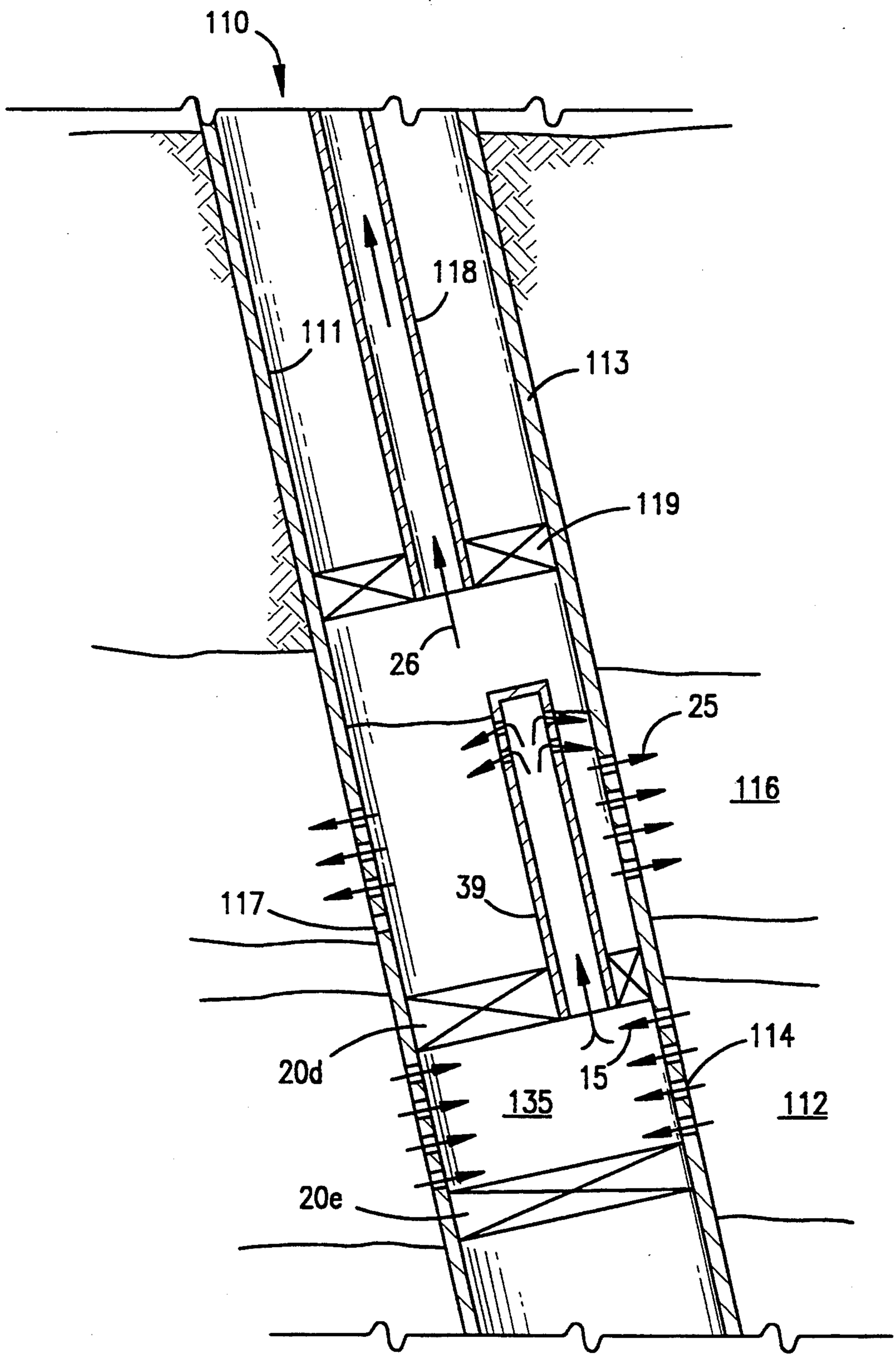


FIG. 5

METHOD FOR IMPROVING PRODUCTIVITY OF A WELL

DESCRIPTION

1. Technical Field

The present invention relates to a method for improving the productivity of a well and in one of its aspects relates to a method for improving the productivity of a hydrocarbon producing well by separating at least a portion of the produced water from the other production fluids downhole in a well and then disposing of the water into a subterranean disposal formation without ever producing the separated water to the surface.

2. Background Art

In producing hydrocarbons (e.g. oil and/or gas) from subterranean formations, a substantial amount of water (e.g. fresh, brine, etc.) is routinely produced along with the desired hydrocarbons from the producing formation. As is universally recognized in the industry, this water creates several problems which adversely affect the productivity of a well and hence, the profitability of the well.

For example, typically all of the produced water must be produced to the surface along with the desired hydrocarbons. The water is substantially heavier than the other produced fluids thereby developing a hydrostatic head or pressure within the production tubing as the fluids are produced to the surface. This hydrostatic pressure applies a back-pressure on the producing formation which, in turn, directly impedes the flow of fluids into the wellbore. If this hydrostatic back-pressure caused by the water being produced to the surface can be reduced, then the productivity of the well will be inherently increased.

Further, substantially all of the produced water has be separated from the hydrocarbons after they reach the surface. This normally requires special equipment and relatively large storage capacities on the surface which, in turn, requires substantial capital outlays and maintenance. Still further, once separated, the water has to be disposed of in an ecologically acceptable manner which usually involves pumping the large volumes of water back into a subterranean disposal formation, which requires additional capital and maintenance.

Accordingly, it can easily be appreciated that the separation and disposal of water in a wellbore without having to produce that water to the surface with the desired production fluids will be highly beneficial to the productivity and the overall ecomonics for that well.

DISCLOSURE OF THE INVENTION

The present invention provides a method for improving the productivity of a well by separating and disposing of at least a portion of the water which is normally produced with the desired fluids (e.g. hydrocarbons) from a subterranean producing formation. Basically, the fluids are produced into the wellbore where at least a portion of the water will separate under the influence of gravity. This separated water is then disposed of without the separated volume of water ever being produced from the wellbore by flowing the separated water into a subterranean disposal formation which has a pressure less than that of said producing formation. Preferably, the well is completed with a wellbore which is inclined from vertical which significantly aids in the gravity separation of the water.

More specifically, the present invention provides a method for increasing or improving the productivity of a producing well (e.g. a hydrocarbon-producing well). Preferably, the well is completed with an inclined, cased wellbore. The casing is perforated adjacent to both the producing formation (e.g. hydrocarbon-producing formation) and a disposal formation (i.e. a formation which is permeable to water and which has a pressure lower than that of the producing formation). It should be recognized that both the producing formation and the disposal formation may be completed open-hole without varying from the present invention.

A string of production tubing is run into wellbore and packer or the like is set to isolate the wellbore above the producing formation. Produced fluids, which normally contains substantial amounts of water, are produced from the producing formation into the wellbore where gravity separation takes place between the lighter fluids (e.g. hydrocarbons such as natural gas, etc.) and the heavier water. The hydrocarbons (e.g. bubbles or molecules of gas, oil, etc.,) will migrate to the high side while the water drops or molecules will move towards the low side of the wellbore.

The separated water flows from the wellbore into the lower-pressured, disposal formation while the production fluids (the produced hydrocarbons and some remaining water) flow upward under differential pressure through the production tubing to the surface. The present invention includes different embodiments of well completions whereby the separated water may be disposed of into a disposal formation which may lie either below or above the producing formation.

While there will likely be some water still remaining in the production fluids when they reach the surface, the volume of water therein will be substantially reduced which, in turn, significantly reduces both (a) the hydrostatic back-pressure on the producing formation and (b) the water separation and handling problems at the surface. Accordingly, the productivity and hence, the profitability, of the well are substantially increased.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and the apparent advantages of the present invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. **1** is a sectional view of a single completion in the lower portion of an inclined wellbore used for separating and disposing of water in accordance with the present invention;

FIG. **2** is a sectional view of a special completion in the lower portion of an inclined wellbore used for separating and disposing of water into a disposal formation which lies below the production formation;

FIG. **3** is a sectional view of a dual completion in the lower portion of an inclined wellbore used for separating and disposing of water in accordance with the present invention;

FIG. **4** is a sectional view of a special dual completion in the lower portion of an inclined wellbore used for separating and disposing of water in accordance with the present invention; and

FIG. **5** is a sectional view of a special completion in the lower portion of an inclined wellbore used for separating and disposing of water into a disposal formation which lies above the production formation in accordance with the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring more particularly to the drawings, FIG. **1** discloses a hydrocarbon-producing well **10** having a wellbore **11** which has been drilled and cased in accordance with conventional procedures. Wellbore **11** passes through several distinct subterranean formations which include hydrocarbon-producing formation **12** (e.g. a relatively high pressure, natural gas producing formation) . As will be understood, casing **13** is perforated to provide perforations **14** adjacent producing formation **12** to allow the produced fluids (arrows **15**) to flow from formation **12** into wellbore **11**. It should be recognized that in some instances, producing formation **12** could be completed open-hole (i.e. not cased).

As is typical in producing wells of this type, the produced fluids **15** will normally include substantial volumes of water (e.g. fresh, brine, etc.) along with the hydrocarbons (e.g. natural gas). Normally, this water has to be produced to the surface along with the hydrocarbons. Unfortunately, the heavier water builds up a hydrostatic head within the wellbore as it is produced to the surface which, in turn, developes a back-pressure on producing formation **12** which impedes and adversely affects flow from the formation **12** (i.e. productivity of the well). Further, the water has to be separated from the hydrocarbons at the surface before the hydrocarbons can be pipelined or the like and the separated water has to be disposed of, usually by pumping it back into a subterranean formation through a disposal well.

In accordance with the present invention, well **10** is completed whereby a substantial volume of the produced water is separated from the hydrocarbons downhole in wellbore **11** and is disposed of into a subterranean formation without the separated volume of water ever being produced to the surface.

In carrying out the present invention, wellbore **11** is logged with standard techniques to locate a disposal formation **16** which is in communication with wellbore **11**. "Disposal formation", as used herein, is meant to be any formation which is permeable to water and which has a pressure lower than that of the production formation. If the permeability of a selected disposal formation (e.g. loose, granular, etc.) is too great, it may be necessary to treat the deposal formation to reduce its permeability before the well is put on production. Several well-known techniques (consolidating, etc.) are available in the art for such treatments. Once a disposal formation **16** is selected, casing **13** is further perforated to provide perforations **17** adjacent disposal formation **16**. Again, although well **10** is illustrated as being cased through disposal formation **16**, it should be understood that the disposal formation does not need to be cased and can be completed open-hole.

A string of production tubing **18** is run into wellbore **11** and packer **19** is set above the producing formation **12** to isolate the wellbore above the producing formation. With unrestricted flow between the producing formation **12** and disposal formation **16**, the well is now ready to be put on production. However, if restricted flow is desired, a packer or plug (dotted lines **20** in FIG. **1**) having a passage **21** therethrough is set in the wellbore **11** below the producing formation **12** before the tubing **18** and packer **19** are run into the wellbore.

Produced fluids **15** flow from producing formation **12**, through perforations **14**, and into wellbore **11**. While the present invention is applicable to substantially vertical wellbores, it is preferred and is highly beneficial to complete at least that portion of wellbore **11** which passes through producing formation **12** at an angle to the vertical, i.e. an "inclined" wellbore. By inclining the wellbore, a much better gravity separation of fluids occurs within the wellbore.

As the produced fluids **15** flow into the wellbore, gravity separation between the lighter hydrocarbons (e.g. natural gas, etc.) and the heavier water begins to take place almost immediately. This gravity separation is enhanced by the inclination of the wellbore **11** at the point of entry of the fluids **15**. The hydrocarbons (e.g. bubbles or molecules of gas, oil, etc., "H" in FIG. 1) will migrate to the high side while the water drops or molecules "W" will move towards the low side in wellbore **11**. The water (arrow **25**) will flow downward in wellbore **11** under the influence of gravity and through perforations **17** into the lower-pressured, disposal formation **16**.

The production fluids (arrow **26**) which are comprised of the produced hydrocarbons and some remaining water flow upward under differential pressure through tubing **18** to the surface. While there is still some water remaining in the production fluids, the volume of water is substantially reduced. This, in turn, significantly reduces both (a) the hydrostatic back-pressure on the producing formation **12** and (b) the water separation and handling problems at the surface. Accordingly, the productivity and hence, the profitability, of the well are substantially increased.

To better illustrate the advantages of the present invention, the following example is set forth. Recently, a gas producing well in West Texas was completed basically as shown in FIG. **1** and described above. The casing in the inclined wellbore was perforated adjacent a producing formation **12** at approximately 16,000 feet and an open-hole disposal formation **16** was identified at a depth of approximately 18,000 feet. The pressures of the producing formation **12** and the disposal formation were 5880 psi and 3590 psi, respectively. After the well was put on production, production logs showed that 1300 mcf of hydrocarbons (i.e. natural gas) and 800 barrels of water were being produced daily while 4200 barrels of water (84 percent of water produced) were being separated and disposed of downhole. Due to the strong water drive in the producing formation and the size and present level of depletion of the disposal formation, it is predicted that the present invention will aid in recovering an additional 1.8 billion cubic feet of gas before the operational life of the well is complete.

Referring now to FIGS. **2–4**, embodiments of different completions are illustrated which can be used to carry out the present invention. In FIG. **2**, inclined well **10** is cased and perforated adjacent producing formation **12** and disposal formation **16** as described above. Lower packer **20**a and upper packer **20***b*, respectively, are set below and above perforations **14** to effectively isolate producing formation **12**. A relatively short string of tubing **30** extends through both packers **20***a* and **20***b* to provide fluid communication between disposal formation **16** and the chamber **35** which is formed between upper packer **20***b* and packer **19** on production tubing **18**. A second relatively short string of tubing **31** also extends through upper packer **20***b* to provide fluid communication between the producing formation **12** and the chamber **35**.

In operation, the produced fluids **15** flow into wellbore **11** through perforations **14** and up into chamber **35** through tubing **31**a in tubing **31** wherein the fluids **15** undergo gravity separation. Water **25** from fluids **15** will accumulate onto the top of upper packer **20***b* until its level reaches the top of tubing **30**, after which water **25** will flow downward through tubing **30** into the disposal formation **16**. Production fluids **25** (i.e. hydrocarbons and the remaining water) will flow upward to the surface through tubing **18**.

FIG. **3** illustrates a well completion which is similar to a conventional dual completed well. Again, while well **10** in both FIGS. **3** and **4** are illustrated as having substantially vertical wellbores **11**, it should be understood that wellbore **11** is preferably inclined from the vertical. In FIG. **3**, wellbore **11** is cased and perforated adjacent producing formation **12** and disposal formation **16** as before. A first string of production tubing **18***a* is lowered and lower packer **20***c* and upper packer **19***a* are set to effectively isolate producing formation **12**. Tubing **18***a* extends through lower packer **20***c* and has a plurality of openings **32** adjacent isolated producing formation **12**. A second string of production tubing **18***b* extends from the surface through upper packer **19***a*.

In operation, produced fluids **15** flow into the wellbore through perforations **14**. After gravity separation of the produced fluids, water **25** will flow through openings **32** in tubing **18***a* downwardly into disposal formation **16** and the production fluids **26** will flow upward through tubing string **18***b*. Some of produced fluids **15** may flow through openings **32** into tubing **18***a* but gravity separation will also occur within the tubing with the water **25** flowing downward and the production fluids flowing upward therein.

FIG. **4** illustrates still another completion which can be used to carry out the invention. Again, well **10** is cased and perforated and upper **19***b* and lower **20***d* packers are used to isolate the production formation **12** as before. A first string of tubing **18***c* having openings **34** therein extends from the surface through the lower packer **20***d*. A second string of tubing **18***d* having opening **33** therein extends from the surface through the upper packer **19***b*.

In operation, the produced fluids **15** flow through perforations **14** into the wellbore between packers **19***b* and **20***d*, up through second tubing string **18***d*, and out openings **33** onto the top of upper packer **19***b* where gravity separation takes place. Water **25**, upon accumulating onto packer **19***b*, will flow through openings **34**, down tubing **18***c*, and into disposal formation **16**.

The completion illustrated in FIG. **5** is designed to separate and dispose of water downhole wherein the disposal formation **116** lies above the producing formation **112**. Well **110** is cased and perforated adjacent both the producing formation **112** and disposal formation **116**. Upper packer **20***d* and lower plug **20***e* are set to isolate producing formation **112** and packer **119** on tubing string **118** is set to form a chamber **135** between packer **20***d* and packer **114**. A relatively short string of tubing **39** extends into chamber **135** through lower packer **20***d*.

In operation, produced fluids **15** flow through perforations **114**, up short tubing **39**, and into chamber **135** where gravity separation takes place. The water **25** flows through perforations **117** into disposal formation **116**. The production fluids flow upward to the surface through production tubing **118**.

What is claimed is:

1. A downhole method for separating and disposing of water from fluids produced from a subterranean producing formation into a wellbore, said method comprising:

completing said wellbore wherein the portion of said wellbore which lies adjacent said production formation is inclined from the vertical;

isolating said portion of said wellbore which lies adjacent said producing formation;

producing produced fluids from said producing formation into said isolated, inclined portion of said wellbore, said produced fluids including water;

allowing at least a portion of said water from said produced fluids to separate from said produced fluids by gravity while said produced fluids are in said isolated, inclined portion of said wellbore; and

disposing of said separated water into a subterranean disposal formation without the separated volume of water ever being produced from said wellbore, said disposal formation having a pressure less than that of said producing formation.

2. The separating and disposal method of claim **1** including:

producing the produced fluids to the surface after said at least a portion of said water has been separated therefrom.

3. The separating and disposal method of claim **2** wherein said disposal formation is below said production formation.

4. The separating and disposal method of claim **2** wherein said disposal formation is above said production formation.

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